Swashzone Fluid Velocities

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Award numbers: N00014-99-1-0193, N00014-00-1-0378
http://science.whoi.edu/PVLAB/index.html

LONG-TERM GOALS

The long-term goal is to develop and verify models for fluid and sediment processes in the swash zone.

OBJECTIVES

The specific objectives of these projects are to:

- measure swashzone fluid velocities at Scripps Beach in Fall 2000.
- collect laboratory observations of swashzone fluid velocities in 2001 and 2002.
- test and improve numerical model predictions of swashzone fluid velocities.

APPROACH

Comparisons of observations with model predictions are being used to investigate swashzone processes, including the runup fluid velocities that are important to sediment transport.

Even though runup excursions owing to random waves on a natural beach are predicted well by a model (Rbreak) based on the vertically-averaged nonlinear shallow water equations with quadratic bottom friction (Kobayashi et al. 1989, Raubenheimer et al. 1995), it is not clear whether the cross-shore velocity u is predicted accurately. A field experiment has been conducted to obtain observations of the cross-shore and vertical structure of cross-shore swashzone fluid velocities. Laboratory studies of swash flows are ongoing. The observations are being compared with Rbreak-predictions and with predictions of models for parameterized bottom boundary layers.

WORK COMPLETED

Surf- and swashzone waves and velocities were measured for 2 weeks during Fall 2000 along a cross-shore transect extending from about 3-m water depth to the shoreline (Figure 1). Downward-looking acoustic Doppler velocimeters (ADV) were deployed at 5 cross-shore locations and provided measurements at elevations above the bed z between 5 and 20 cm. Sets of three horizontal-looking ADV probes were stacked vertically at z = 2, 5 and 8 cm at two cross-shore locations. During low tides, the swashzone sensors were adjusted vertically to maintain approximately constant elevations above the bed. However the sample volume elevations fluctuated about ± 5 cm owing to sand level

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**
4. TITLE AND SUBTITLE **Swashzone Fluid Velocities**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,,266 Woods Hole Road, MS # 12,,Woods Hole,,MA, 02543**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

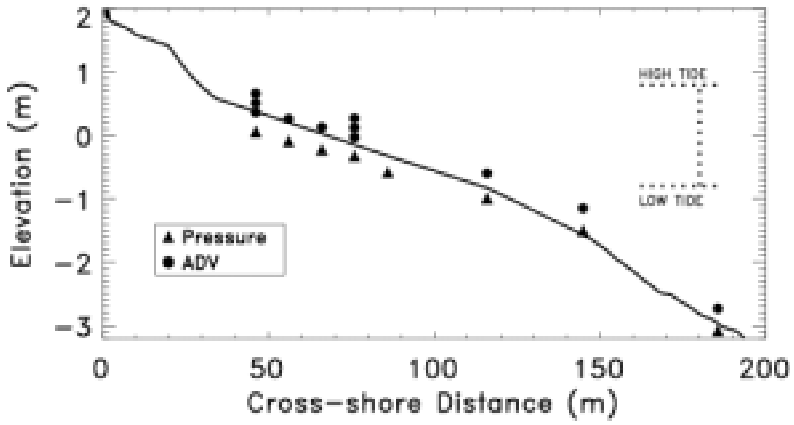

Figure 1. Scripps Beach profile (solid curve, slope ≈ 0.02) measured on Sep 28, 2000, and locations of acoustic Doppler velocimeters (ADV, solid circles) and pressure sensors (solid triangles). Sensors were deployed in mean water depths –31.5, -14.5, -9.4, 6.1, 24.0, 82.9, 132.3, and 284.0 cm (negative values are above mean sea level).

changes during a tidal cycle, and fluid velocities were measured as close to the bed as z = 0.5 cm. Pressure sensors, buried just below sand level to measure wave and runup heights, were collocated with the velocimeters.

Particle Image Velocimetry (PIV) and Laser Doppler Velocimetry (LDV) measurements of swashzone fluid velocities are being collected in a 32 m long, 0.6 m wide, 0.9 m deep wave tank in the DeFrees Hydraulic Laboratory at Cornell University. Preliminary measurements have been conducted for plunging type waves with a 2 s wave period. Cross-shore and vertical velocities were observed at 15 Hz for 332 s and ensemble-averaged resolving 30 wave phases.

RESULTS

Field observations of the cross-shore structure of significant wave heights, root-mean-square orbital velocities, and mean offshore-directed flows in the surf and swash zones are predicted well by a numerical model based on the 1-dimensional depth-averaged nonlinear shallow water equations. Wave heights decrease monotonically with decreasing water depth, whereas orbital velocities and mean flows reach a local maximum near the outer swash zone (Figure 2). Velocity asymmetry is sensitive to mean water depth (and cross-shore location) within the swash zone. Although sea-swell asymmetry is large and positive (suggesting strong onshore-directed acceleration at the wave fronts), infragravity asymmetry decreases across the swash zone becoming negative at the most onshore locations. The numerical model predicts qualitatively the cross-shore structure of velocity-shapes. However, swashzone velocity skewness, uprush velocities, and sea-swell asymmetry, which may be important to sediment transport, are overpredicted.

The observations suggest that the cross-shore velocities are not uniform in the vertical (Figure 3), as assumed in the depth-averaged nonlinear shallow water equations. Within about 5 cm of the bed, u

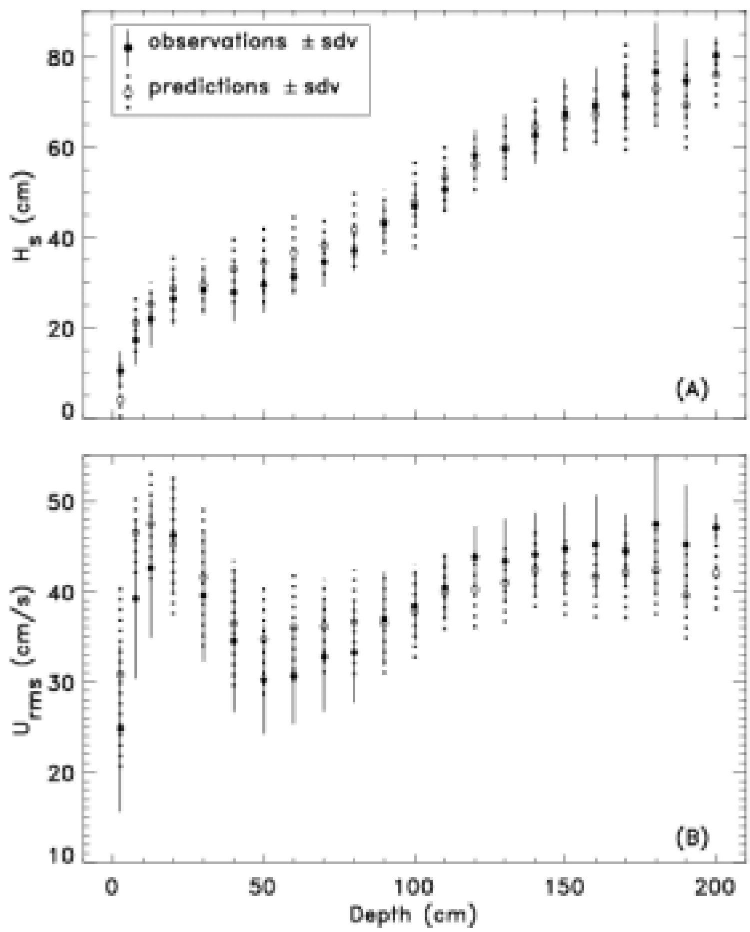

Figure 2. (A) Observed and predicted significant wave heights (H_s) decrease monotonically with decreasing depth, with the ratio of significant wave height to water depth ≈ 0.5. (B) Observed and predicted root-mean-square (U_{rms}) cross-shore velocities slowly decrease from about 44 to 33 cm/s as water depth decreases from 200 to 40 cm, then increase to a local maximum of about 46 cm/s in the outer swash zone (depth ≈ 20 cm) before rapidly decreasing to the shoreline.

decreases with decreasing *z* during the rundown, but is nearly constant over the vertical during runup. Preliminary results suggest that the vertical structure of the horizontal velocities is described well by a logarithmic profile, possibly related to a turbulent bottom boundary layer.

IMPACT/APPLICATIONS

Validated models of wave runup velocities may provide spatially dense predictions of cross-shore and alongshore swashzone flows to drive sediment transport models and to estimate morphological change. It is expected that these observations and field-tested models also will be useful to extend surfzone models into the swash zone. Evaluations of boundary layer parameterizations may provide a basis for revising time-domain models that assume quadratic bottom stresses.

TRANSITIONS

RELATED PROJECTS

Observations from the in situ sensors of SwashX are being used to evaluate estimates of swash and surf zone velocities using drifters (W. Schmidt and R.T. Guza, Scripps Inst. Oceanography), a video-based PIV technique (J. Puleo and T. Holland, Naval Research Laboratory), and FOPAIR (G. Faquharson and S. Frasier, U. Mass. Dartmouth).

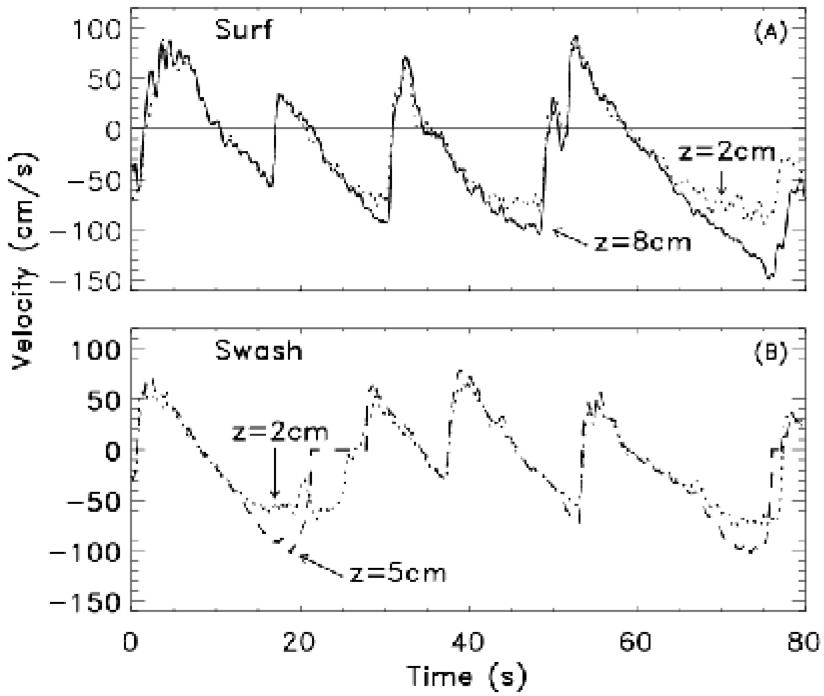

Figure 3. Cross-shore velocities (positive is onshore) measured (A) on Oct 11 in the inner surf zone (depth ≈ 26 cm) and (B) on Sep 30 in the swash zone (depth ≈ 11 cm) are observed to decrease towards the bed (with decreasing z) during offshore flows. In the swash zone, velocities are set equal to 0.0 cm/s when a sensor is out of the water.

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